Tin

What Is It? Tin is a soft, silvery white metal with a highly crystalline structure that is malleable and ductile. When a bar of tin is bent, a crackling sound is emitted caused by the friction of the tin crystals. Tin exists in nature as nine stable isotopes. (Isotopes are different forms of an element that have the same number of protons in the nucleus, but a different number of neutrons.) These nine isotopes and their approximate abundances are tin-112 (1.0%), tin-114 (0.7%), tin-115 (0.3%), tin-116 (15%), tin-117 (7.7%), tin-118 (24%), tin-119 (8.6%), tin-120 (33%), tin-122 (4.6%), and tin-124 (5.8%).

Symbol:	**Sn**
Atomic Number: *(protons in nucleus)*	**50**
Atomic Weight: *(naturally occurring)*	**119**

Thirteen major radioactive isotopes of tin exist of which only two – tin-121m and tin-126 – have half-lives long enough to warrant concern at Department of Energy (DOE) environmental management sites such as Hanford. Tin-121m has a half-life of 55 years, and tin-126 has a half-life of 250,000 years; the half-lives of the other isotopes are less than one year. Both isotopes are fission products, with the fission yield of tin-126 being significantly larger than the yield of tin-121m. Thus, tin-126 is the more prevalent isotope at DOE sites. While tin-126 has a low specific activity that tends to limit its radioactive hazards, its short-lived daughter antimony-126 has a high gamma component, making external exposure to tin-126 a potential concern.

Radioactive Properties of Key Tin Isotopes and Associated Radionuclides

Isotope	Half-Life	Specific Activity *(Ci/g)*	Decay Mode	Radiation Energy *(MeV)*		
				Alpha (α)	Beta (β)	Gamma (γ)
Sn-121m	55 yr	54	β, IT	-	0.035	0.0049
Sn-121 (78%)	*27 hr*	*970,000*	*β*	-	*0.11*	-
Sn-126	250,000 yr	0.029	β	-	0.17	0.057
Sb-126	*12 d*	*85,000*	*β*	-	*0.28*	*2.8*

IT = isomeric transition, Ci = curie, g = gram, and MeV = million electron volts; a dash means the entry is not applicable. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Tin-121m decays by two means: emitting a beta particle (22%) and isomeric transition (78%). Certain properties of tin-121 and antimony-126 are included here because these radionuclides accompany the tin decays. Values are given to two significant figures.

Where Does It Come From? The principal ore of tin is the mineral cassiterite (tin oxide, SnO_2) found either in rocks within often irregular veins or lodes, or in debris that has built up from the gradual wearing down of tin-bearing rocks to form alluvial deposits found in river beds and valleys or on the ocean floor close to shore. Most of the world's tin is produced by Malaysia, Brazil, Indonesia, Thailand, Bolivia, and Australia. The United States imports more than one-fifth of the average annual world production of tin.

Tin-121m and tin-126 are produced by nuclear fission. When an atom of uranium-235 (or other fissile nuclide) fissions, it generally splits asymmetrically into two large fragments – fission products with mass numbers in the range of about 90 and 140 – and two or three neutrons. (The mass number is the sum of the number of protons and neutrons in the nucleus of the atom.) Tin-121m and tin-126 are two such fission products; the fission yield of tin-121m is very low (about 0.00003%), while the fission yield of tin-126 is about 0.06%. That is, much less than one atom of tin-121m and six atoms of tin-126 are produced per 10,000 fissions. These two tin isotopes are components of spent nuclear fuel, high-level radioactive wastes resulting from processing spent fuel, and radioactive wastes associated with the operation of nuclear reactors and fuel reprocessing plants.

How Is It Used? Tin is used in a number of industrial processes throughout the world. Tinplate (sheet steel coated with a thin layer of tin) is the primary material used for food cans, and tin is also commonly used in bakeware and food storage containers. Tin is used to produce common alloys such as bronze (tin and copper) and solder (tin and lead). It is also used as an alloy with titanium in the aerospace industry and as an ingredient in some insecticides. Stannic sulfide, also known as mosaic gold, is used in powdered form for bronzing articles made of plaster of paris or wood. Dental amalgam contains about 13% tin together with silver and mercury, and mercury-free alternative dental filling materials with about twice the amount of tin are under development. Tin and tin-alloy coatings are widely used in the manufacture of bearings and in many kinds of machinery and fabricated parts, for both their anti-corrosion and lubricant properties.

What's in the Environment? Tin is present in the earth's crust at a concentration of about 2.2 milligram per kilogram (mg/kg), and its concentration in seawater is about 0.01 micrograms (µg) per liter. Trace amounts of tin-121m and tin-126 are present in soil around the globe from radioactive fallout. These isotopes can also be present at certain nuclear facilities, such as reactors and facilities that process spent nuclear fuel. Tin is generally one of the less mobile radioactive metals in soil, although certain forms can move downward with percolating water some distance to underlying layers of soil depending on site conditions. Tin preferentially adheres quite well to soil, and the concentration associated with sandy soil particles is estimated to be about 130 times higher than in interstitial water (the water in the pore spaces between the soil particles), with even higher concentration ratios in loam and clay. Thus, tin is generally not a major contaminant in groundwater at DOE sites. The highest concentrations of tin at Hanford are in areas that contain waste from the processing of irradiated fuel, such as the tanks in the central portion of the site, and to a lesser degree in liquid disposal areas along the Columbia River.

What Happens to It in the Body? Tin can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is the principal source of internally deposited tin in the general population. Gastrointestinal absorption is generally quite low, with only about 2% of the amount ingested being transferred to the bloodstream. Thirty-five percent of tin that reaches the blood is deposited in mineral bone, 15% is distributed throughout all other organs and tissues of the body, and the remaining 50% is excreted. Of the tin deposited in any organ or tissue, 20% is retained with a biological half-life of 4 days, 20% is retained with a biological half-life of 25 days, and 60% is retained with a biological half-life of 400 days. (This information is per simplified models that do not reflect intermediate redistribution.)

What Are the Primary Health Effects? Tin poses an external as well as an internal health hazard. The strong gamma radiation associated with tin-126 makes external exposure to this isotope a concern. The main means of internal exposure are ingestion of food and water containing tin isotopes. While in the body, tin poses a health hazard from both the beta particles and gamma rays, and the main health concern is associated with the increased likelihood of inducing cancer in bone and other organs and tissues in which it may be deposited.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including tin *(see box at right)*. While the coefficients for ingestion are lower than for inhalation, ingestion is generally the most common means of entry into the body. Similar to other radionuclides, the risk coefficients for tap water are about 70% of those for dietary ingestion.

In addition to risks from internal exposures, there is an external gamma exposure risk associated with tin-126. To estimate a lifetime cancer mortality risk, if it is assumed that 10,000 people were continuously exposed to a thick layer of soil with an initial average concentration of 1 pCi/g tin-126, then 6 of these 10,000 people would be predicted to incur a fatal cancer. (This is in comparison to the 2,500 people from this group predicted to die of cancer from all other causes per the U.S. average.) This risk is largely associated with the gamma ray emitted by its short-lived decay product antimony-126.

Radiological Risk Coefficients

This table provides selected risk coefficients for inhalation and ingestion. Maximum values are given for inhalation (no default absorption types were provided), and dietary values were used for ingestion. These values include the contributions from the short-lived tin decay products. Risks are for lifetime cancer mortality per unit intake (pCi), averaged over all ages and both genders (10^{-9} is a billionth, and 10^{-12} is a trillionth). Other values, including for morbidity, are also available.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation *(pCi^{-1})*	**Ingestion** *(pCi^{-1})*
Tin-121m	4.1×10^{-11}	2.9×10^{-12}
Tin-126	3.9×10^{-10}	3.0×10^{-11}

For more information, see the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients and accompanying Table 1.